PROSODIC DISAMBIGUATION OF EARLY CLOSURE/LATE CLOSURE SENTENCES

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ABSTRACT
Participants listened to a syntactically ambiguous string (e g *When that moves the square*) spoken with one of three prosodies Cooperating (prosodic boundary coincides with syntactic boundary), conflicting (prosodic boundary differs from syntactic boundary), and ambiguous (equal or no prosodic breaks at both syntactic boundaries) They selected an early closure syntax continuation or a late closure syntax continuation, in one of two segmental conditions /t/ or /w/ Sentence continuations were either the originally recorded sentence continuations (e g early closure *will encounter a cookie,* late closure *it should land in a good spot*) or a set of continuations that counterbalanced phrase-initial phonological information with syntactic structure (e g early closure *is shut out from the best path*, late closure *we'll encounter a problem*) The experiment demonstrated that prosodic phrasing differentially affected selection accuracy (per cent correct and judgment confidence) Regardless of initial phonological information, sentence fragments with cooperating prosody demonstrated greatest accuracy, those with ambiguous prosody had a smaller degree of accuracy, and fragments with conflicting prosody were identified least accurately In fact, conflicting prosody for late closure sentences resulted in misidentification We argue that naive listeners can use prosodic structure to determine the syntactic structure assigned to an utterance

INTRODUCTION

A literate speaker/hearer's intuition may suggest that language comprehension is the same, regardless of whether the language is written or spoken However, written language does not retain the full range of features and structures present in oral language The prosodic structure of an utterance is one characteristic of oral language that is not well-represented in a visually presented text Although speakers can use a variety of prosodic elements to convey information—phrasing, word and pause duration and location, amplitude and changes in fundamental frequency values, for purpose of this study, prosody refers to the stress, rhythm and intonation of the spoken sentences Prosody can be used to convey such things as topic focus, focus narrowing or expansion, backgrounding and foregrounding of information, demarking new and given information, adding emotional tone to an utterance and syntactic disambiguation (Bock,1995, Warren, 1996,1997, Shattuck-Hufnagel, et al , 1996, Cutler, et al, 1997, Beckman, 1996)

Past studies on the role of prosody in syntactic disambiguation have presented a mixed picture (Beach, 1991, Speer, Kjelgaard and Dobroth, 1996, Warren, Grabe and Nolan, 1997, and Kjelgaard and Speer 1999) While the majority of sentence comprehension studies support the notion that prosodic structure is used to disambiguate a variety of syntactic structures for the listener, some have found no effect of prosody on syntactic processing (Watt & Murray, 1996) In addition, there is some question as to whether listeners rely on prosodic information or phonological information from the coarticulation in disambiguating syntactic structure (Cutler and Norris, 1979). Listeners may be relying on the coarticulation of the phonological segments across word boundaries rather than prosodic information in making such judgments In experiments closely related to those we present here, Kjelgaard and Speer (1999) found that cooperating prosody facilitated syntactic disambiguation of early closure/late closure

sentences, while conflicting prosody impeded disambiguation and ambiguous prosody neither facilitated nor impeded disambiguation However, the role of coarticulation was not addressed in that study

Some recent sentence production studies have suggested that the production of disambiguating prosodic information may be an artifact of the experimental situation Beach (1991) and Allbritton, et al, (1996) found that prosodic boundaries are not consistently marked by speakers and may not be produced at all when the speakers are not trained phoneticians, radio announcers or actors These findings call into question whether listeners generally use prosodic information for disambiguation if prosodic structure only appears in highly artificial situations In contrast to the earlier studies, Speer, Shafer & Warren (1999) found that naive speakers do produce disambiguating prosody in natural discourse situations Specifically, they found that naive speakers used prosodic phrasing to disambiguate syntactic information in early closure and late closure sentences

The purpose of the experiment presented here is to determine whether naive listeners can use prosodic information from the utterances of naive speakers to disambiguate early closure/late closure syntactic structure Early closure/late closure syntax refers to the transitive/intransitive distinction with early closure being the intransitive structure (no direct object) and late closure being the transitive structure (verb is followed by a direct object)

Intransitive (EC) *When that moves, the square will land in a good spot*

Transitive (LC) *When that moves the square, it should encounter a cookie*

The experiment includes three prosodic conditions like those used in Kjelgaard and Speer (1998) in a syntactic disambiguation task These include cooperating prosody, where major prosodic and syntactic boundaries coincide, conflicting prosody where the major prosodic boundary occurs at a misleading location in a syntactic structure, and ambiguous prosody, where the location of the prosodic boundaries corresponds equally well to either syntactic structure

This experiment will use sentence fragments taken from the set of early closure/late closure sentences produced by naive speakers in Speer, Shafer & Warren (1999) Naive listeners will hear syntactically ambiguous fragments (*when that moves the square*) spoken with a variety of prosodic structures After each fragment, they will select one of two visually presented disambiguating sentence continuations and rate their degree of confidence in their selection If results are consistent with those from studies using trained speakers, we expect to find that cooperating prosody facilitates correct judgment, conflicting prosody impedes it, and ambiguous prosody neither contributes to nor takes away from correct judgment

In order to determine whether listeners rely upon prosodic boundary information alone to disambiguate syntactic structure, or whether they also rely on information from the coarticulation of phonological segments, coarticulation was included as an experimental variable Adjacent phonemes in a spoken sentence are frequently articulated by gestres that overlap in time Such coarticulatory effects are found within and between words In our materials, if the fragment '*when that moves the square*' was originally spoken before the word *'will,'* coarticulatory traces of the */w/* might be present at the end of '*square* ' These traces might influence the listener to select a continuation that begins with */w/* To examine this issue, we used two sets of sentence continuations the original sentence continuations, and a set of continuations that counterbalanced phonological information and syntactic structure If listeners

make judgments based only on coarticulation, they should select the sentence continuation that matches the final phonological segment of the sentence fragments regardless of prosodic information In the original sentence continuation condition listeners would choose the correct continuation, but in the counterbalanced sentence continuation condition, they would choose the incorrect continuation We predict that segmental information coinciding with prosodic information would facilitate disambiguation, while segmental information contrary to prosodic information would be disregarded That is, we expected to find that prosodic phrasing information provides such a powerful cue to syntactic continuation that it can override conflicting segmental information

METHOD

SUBJECTS

Nineteen University of Kansas undergraduates participated in return for partial credit toward a course requirement in an introductory psychology course All participants were native speakers of English with normal or corrected-to-normal vision and no reported hearing problems Data from two were discarded because their accuracy in all conditions was at chance, and anecdotal observations indicated that they were not making purposeful judgments The data for a third participant were lost due to experimenter error

DESIGN and MATERIALS

106 utterances produced by 12 speakers collected by Speer, Shafer & Warren (1999) were used as listening stimuli The utterances all began with the same syntactically ambiguous string of words 53 continued with an intransitive structure, while 53 continued with a transitive structure

Syntactically ambiguous string	*When that moves the square*
Early closure continuation	*will encounter a cookie*
Late closure continuation	*it should land in a good spot*

The utterances were digitally truncated at the point of disambiguation, after the word *square* and following silence, if any Two separate teams of trained phoneticians transcribed the utterances to determine the location and magnitude of prosodic breaks in the sentence fragments Fragments were sorted into three groups by transcription The largest prosodic break occurred after *moves*, the largest prosodic break occurred after *square*, or there were equal breaks (i e , ambiguous prosody) (See Speer, Shafer, Warren, White, and Kneale (1999) for details of transcription method and results)

Four written continuations were constructed for the selection task One pair of continuations consisted of the exact words from the original early and late closure continuations (the original continuations) A second pair of continuations was created to determine whether listeners rely on prosodic information or on clues from coarticulation of phonological segments to disambiguate syntactic structure (the counterbalanced continuations) These continuations either had early closure syntax and an initial phonological segment that corresponds to the original late closure initial segment */l/* or late closure syntax with the initial phonological segment that corresponds to the original early closure initial segment */w/*

The design had three within-subject factors

- syntax—the syntactic structure of the original utterance, as intended by the naive speaker

early closure (intransitive) (EC)
late closure (transitive) (LC)

- prosody—prosodic conditions are defined according to prosodic boundary locations
  - cooperating prosody -- Major prosodic and syntactic boundaries coincide (For EC the largest prosodic break occurs after *moves*, for LC the largest prosodic break occurs after *square*)
  - conflicting prosody – Major prosodic boundary is in a misleading syntactic location (For LC, the prosodic break occurs after *moves*, for EC, the prosodic break occurs after *square*)
  - ambiguous prosody -- There are equal prosodic breaks at the locations following *moves* and *square*
- visual sentence continuations—This variable allows us to examine effects of coarticulation
  - Original spoken ending (phoneme beginning the continuation matches coarticulation)
    - early closure - *will encounter a cookie*
    - late closure - *it should land in a good spot*
  - Constructed ending (phoneme beginning the fragment conflicts with coarticulation)
    - early closure - *is shut off from the best path*
    - late closure - *we'll encounter a problem*

PROCEDURE

Participants were seated in a quiet room with headphones, a computer monitor, and a keyboard and mouse They were asked to listen to sentence fragments presented over the headphones On each trial, a sentence fragment was presented twice with a 3 second delay between presentations Immediately after the fragment had been presented, two sentence continuations appeared on the computer monitor Participants were asked to select the sentence continuation that they thought completed the sentence and then to rate their degree of confidence in their selection on a scale of 1-6, with 1 being very sure and 6 being not at all sure There were two blocks of 106 trials separated by 5-10 minute break Four sets of materials were created for presentation Within sets, the sentence fragments were blocked by speaker, and speaker order was counterbalanced across sets Sentence continuation was counterbalanced so that half the time, original continuation pairs were presented before the break, and half the time, the constructed continuation pairs were presented before the break Finally, presentation before or after the break was crossed with the location on the screen of the completion phrase so that early vs late closure completions and the /w/ vs /I/ completions occurred on the left and right sides of the screen on an equal number of trials

Originally there were two dependent variables in this within subjects design Per cent correct response and degree of confidence rating To look at both variables simultaneously, the scores were converted into a 12-point scale of selection accuracy, reflecting both correctness and confidence (12 = correct response, very confident, 1 = incorrect response, very confident) The conversion procedure and resulting rating scale were adapted from recognition-memory paradigms (Murdock, 1974, Speer, Crowder and Thomas, 1996) Pollard & Decker (1958) determined that this type of scale not only exhibits efficiency but also does not differ in measured sensitivity from the two variables used separately The constructed selection accuracy variable is the dependent variable in this within-subjects repeated measures ANOVA design

RESULTS

A three factor (prosody X syntax X sentence continuations) within-subjects repeated measures ANOVA was used to examine the data The main effects of prosody and syntax were significant (F (2,30) = 43 96, p= 0001, and F (1,15) = 7 81, p= 0136, respectively) Prosody x syntax was the only significant two-way interaction effect, F(2,30)=8 921, p= 0009, indicating correctness and confidence in sentence continuation selections differed across syntactic conditions depending on the prosodic condition The mean accuracy scores for the prosody X syntax conditions are reported in Table 1

	PROSODIC STRUCTURE		
SYNTAX OF ORIGINAL UTTERANCE	Ambiguous	Cooperating	Conflicting
Intransitive (EC)	8 2	9 2	8 0
Transitive (LC)	7 9	9 3	6 2

Table 1 Mean accuracy scores for prosody X syntax conditions

There were no significant effects of the variable sentence continuations, nor did it significantly interact with other variables This suggests that segmental information (sentence continuation) does not mediate the effect of prosodic condition across syntactic conditions, as we had predicted

Planned comparison contrasts between prosodic conditions with segmental information collapsed across all conditions were all significant Judgments in the cooperating conditions were more accurate than those in the ambiguous (F (1,1) = 19 27, p= 0001), judgments in the cooperating conditions were more accurate than those in conflicting, (F (1,1) = 62 47, p= 0001), and judgments in the ambiguous conditions were more accurate than those in the conflicting conditions (F (1,1) = 12 35, p= 0014)

DISCUSSION

Selection accuracy was the highest in the cooperating prosodic condition across both syntactic conditions indicating not only that listeners successfully relied on prosodic information to disambiguate syntactic structure, but that they were very confident about their selections In addition, early closure structures and late closure structures were identified with approximately the same degree of accuracy in the cooperating prosody condition Cooperating prosody facilitates syntactic disambiguation of both structures equally well

As predicted, selection accuracy for fragments with ambiguous prosody was lower than fragments with cooperating prosody across both syntactic conditions However, the means (7 9—8 2) indicate that syntactic structures were identified correctly more often than predicted Both early and late

closure structures were identified with approximately the same relatively high degree of accuracy, even though prosodic phrasing information was ambiguous

In contrast, accuracy in the conflicting condition was not only significantly lower than in the cooperating prosody or ambiguous prosody conditions, but it revealed a large differential performance across syntactic conditions Conflicting prosody in the late closure condition led to incorrect sentence continuation selection That is, recovery of the late closure syntactic analysis was particularly impeded by conflicting prosody (prosodic break after *moves*) This difference in the conflicting conditions largely accounts for the main effect of syntax

This study replicated the Kjelgaard and Speer 1999 findings that cooperating prosody can resolve temporary syntactic closure ambiguity, while conflicting prosody impedes syntactic disambiguation for these structures However, we also found syntactic disambiguation in the ambiguous prosodic conditions, although it was to a lesser degree than in the cooperating condition While the ambiguous prosody led to less confidence in judgment than was found in the cooperating condition, participants were still able to select the correct continuation for both early and late closure fragments The facilitative effect of cooperating prosody combined with the impedance effect of conflicting prosody provide evidence that prosodic structure is a viable information source separate from syntactic structure for processing oral language

We also found that segmental information (coarticulation) did not appear to be information that listeners relied on to make forced-choice sentence continuation selections We found no evidence that performance in the original sentence continuation condition differed from the counterbalanced condition, indicating that listeners did not use segmental information in the counterbalanced condition The finding that the counterbalanced sentence endings were still correctly identified indicates that phrasing information supplied by the prosodic structure overrode the segmental cues provided by coarticulation Listeners use prosodic information rather than segmental information in making their sentence completion judgements This finding is contrary to the findings that the Cutler and Norris study (1979) would have predicted Our results suggest that when segmental information from coarticulation conflicts with information available from prosodic phrasing, listeners rely on prosodic information, not segmental information in determining syntactic relations during the processing of oral language

Finally, the much poorer performance in the conflicting prosodic condition for late closure syntax is contrary to the expectations from syntactic disambiguation studies of written text Eye tracking studies indicate that the late closure structure is the preferred 'first pass' analysis of the early/late closure sentence, otherwise known as garden pathing If the language processing system first interprets this ambiguous syntactic structure as a late closure structure, the expectation would be that the early closure sentence continuations would be misidentified in the conflicting prosodic condition (large break after *square*) The opposite pattern emerged in the data in the conflicting prosody condition, early closure continuations were correctly identified more often than late closure continuations It would appear that the large prosodic break after *moves* misled participants to select the early closure rather than the late closure continuation That is, prosodic information outweighed syntactic information Viewed in this way, our results from the processing of auditory language point to a different garden pathing than

eye tracking studies Early closure prosody creates a first pass analysis of early/late closure sentences as early closure disambiguation At the very least, these findings would indicate that auditory language is processed somewhat differently than written language Listeners use prosodic information to organize and disambiguate the sound stream The fact that prosodic information is poorly represented in written text could be an explanation for why language processing of written text exhibits the opposite disambiguation patterns than auditory texts A language processing model needs to address the role of prosodic structure in the processing of orally produced language Prosodic structure would appear to be a more primary organizing structure for processing language than syntax

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